

CLAIMS

1. An optical integrator, comprising:

an integrally formed plurality of first minute refraction surfaces; and

5 an integrally formed plurality of second minute refraction surfaces, which are provided closer to a light emission side than the plurality of first minute refraction surfaces so that the plurality of second minute refraction surfaces optically correspond to the plurality of first minute refraction surfaces, wherein

a parameter β satisfies the following conditions:

$|\beta| < 0.2$ (where $\beta = (\gamma - 1)^3 \cdot NA^2 / \Delta n^2$), where

a refracting power ratio ϕ_a / ϕ_b between ϕ_a , a refracting power of the first minute refraction surfaces and ϕ_b , a refracting power of the second minute refraction surfaces is γ , numerical aperture on the emission side of the optical integrator is NA , and a difference between a refraction index of a medium on a light entrance side of the second minute refraction surfaces and a refraction index of a medium on a light emission side of the second minute refraction surfaces is Δn .

2. The optical integrator according to claim 1, wherein the plurality of first minute refraction surfaces and the plurality of second minute refraction surfaces are formed on the same optical member.

3. The optical integrator according to claim 1, comprising:

a first optical member having the plurality of first minute refraction surfaces; and

5 a second optical member having the plurality of second minute refraction surfaces arranged on a light emission side of the first optical member.

4. The optical integrator according to any of claims 1 to 3, wherein the plurality of second minute refraction surfaces comprise aspherical surfaces.

10 5. An optical integrator, comprising in the order from a light entrance side:

a first optical member having an integrally formed plurality of first minute refraction surfaces; and

15 a second optical member having an integrally formed plurality of second minute refraction surfaces, which are provided to optically correspond to the plurality of first minute refraction surfaces, wherein

20 a refraction index of an optical material forming the second optical member is set larger than a refraction index of an optical material forming the first optical member.

6. The optical integrator according to claim 5, satisfying the following condition:

25
$$0.05 \leq n_b - n_a, \text{ where}$$

the refraction index of the optical material forming the first optical member is n_a , and the refraction index of the optical material forming the second optical member is n_b .

5 7. The optical integrator according to claim 5 or claim 6, which is used for light having a wavelength of 300 nm or less, wherein

the optical material forming the first optical member includes silica glass or fluorite, and wherein

10 the optical material forming the second optical member includes one material of magnesium oxide, ruby, sapphire, quartz crystal, and silica glass.

15 8. The optical integrator according to claim 5 or claim 6, which is used for light having a wavelength of 300 nm or less, wherein

the optical material forming the first optical member includes fluorite, and wherein

the optical material forming the second optical member includes silica glass.

20 9. The optical integrator according to any of claims 1 to 8, wherein

each minute refraction surface is formed spherically or aspherically.

25 10. The optical integrator according to any of claims 4 to 9, wherein

the aspherical surface is a rotational symmetry

aspherical surface or a rotational asymmetry aspherical surface.

11. The optical integrator according to any of claims 1 to 10, used for

5 an exposure apparatus, wherein a mask and a photosensitive substrate are relatively moved in relation to a projection optical system along a scanning direction, and thereby a pattern of the mask is projected and exposed on the photosensitive
10 substrate, wherein

 an absolute value of the parameter β in terms of a direction optically approximately perpendicular to the scanning direction is set lower than an absolute value of the parameter β in terms of the scanning
15 direction.

12. An illumination optical device for illuminating an irradiated surface, comprising:

 the optical integrator according to any of claims 1 to 11.

20 13. The illumination optical device according to claim 12, wherein the optical integrator forms a light intensity distribution in a given shape in an illumination region.

14. An exposure apparatus, comprising:

25 the illumination optical device according to claim 12 or claim 13; and

a projection optical system for projecting and exposing a pattern of a mask arranged on the irradiated surface on a photosensitive substrate.

15. The exposure apparatus according to claim 14,
5 wherein

the pattern of the mask is projected and exposed on the photosensitive substrate by relatively moving the mask and the photosensitive substrate in relation to the projection optical system along a scanning
10 direction, and wherein

an absolute value of the parameter β in terms of a direction optically approximately perpendicular to the scanning direction is set lower than an absolute value of the parameter β in terms of the scanning
15 direction.

16. An exposure method, wherein

a mask is illuminated through the illumination optical device according to claim 12 or claim 13, and wherein

20 an image of a pattern formed on the illuminated mask is projected and exposed on a photosensitive substrate.

17. The exposure method according to claim 16, wherein

25 the pattern of the mask is projected and exposed on the photosensitive substrate while the mask and the

photosensitive substrate are relatively moved in relation to a projection optical system along a scanning direction, and wherein

an absolute value of the parameter β in terms of a direction optically approximately perpendicular to the scanning direction is set lower than an absolute value of the parameter β in terms of the scanning direction.

18. An exposure apparatus, comprising:

an illumination optical system including an optical integrator; and

a projection optical system for forming a pattern image of a mask on a photosensitive substrate, wherein

the pattern of the mask is projected and exposed on the photosensitive substrate while the mask and the photosensitive substrate are relatively moved in relation to the projection optical system along a scanning direction, wherein

the optical integrator comprises: an integrally formed plurality of first minute refraction surfaces; and an integrally formed plurality of second minute refraction surfaces, which are provided closer to a light emission side than the plurality of first minute refraction surfaces so that the plurality of second minute refraction surfaces optically correspond to the plurality of first minute refraction surfaces, and

wherein

a parameter β satisfies the following conditions:

$|\beta| < 0.2$ (where $\beta = (\gamma - 1)^3 \cdot NA^2 / \Delta n^2$), where

5 a refracting power ratio ϕ_a / ϕ_b between ϕ_a , a
refracting power of the first minute refraction
surfaces in terms of a nonscanning direction optically
approximately perpendicular to the scanning direction
and ϕ_b , a refracting power of the second minute
refraction surfaces in terms of the nonscanning
10 direction is γ , numerical aperture on the emission side
in terms of the nonscanning direction of the optical
integrator is NA , and a difference between a refraction
index of a medium on a light entrance side of the
second minute refraction surfaces and a refraction
15 index of a medium on a light emission side of the
second minute refraction surfaces is Δn .